

COMMONWEALTH OF PENNSYLVANIA.

DEPARTMENT OF AGRICULTURE.

BULLETIN No. 58.

A CHEMICAL STUDY OF THE APPLE AND ITS PRODUCTS.

By C. A. BROWNE, JR.



PUBLISHED BY DIRECTION OF THE SECRETARY.

1899.

WM. STANLEY RAY,
STATE PRINTER OF PENNSYLVANIA.
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Department of Agriculture.

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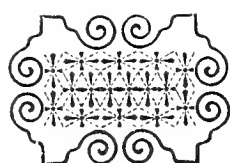
The accompanying Bulletin upon "A Chemical Study of the Apple and Its Products," by C. A. Browne, Jr., Assistant Chemist in the State College Experiment Station, deals with a most important industry, and one for which Pennsylvania soil and climate seem to be especially well adapted.

The States East of us have given careful attention to the development of fruit culture, particularly to the growing of apples, until not only are the large orchards set with approved varieties, but the owners of only a few trees are also careful to select the best and see that they are properly cultivated and the fruit harvested and marketed in good condition.

Pennsylvania farmers are coming to realize that fruit, instead of going to waste, ought to contribute a considerable percentage to their annual income, and are after reliable information to use in improving the quality and increasing the quantity of this crop.

Fruit growers and consumers, therefore, will be interested in the discussion of the chemical constituents of the apple and its products, as presented in this Bulletin, and its careful study will enable them more intelligently to engage in this branch of our agriculture and appreciate the high standard of excellence which it is possible to attain.

JOHN HAMILTON,
Secretary of Agriculture.



A CHEMICAL STUDY OF THE APPLE AND ITS PRODUCTS.

BY C. A. BROWNE, JR.,

(Assistant Chemist, Pennsylvania State College Agricultural Experiment Station.)

INTRODUCTION.

No other fruit has achieved a wider or more universal popularity than the apple. Other fruits have their distinctive and well appreciated qualities, but for general excellency and extent of culture, the apple surpasses them all. The chief reason for this wonderful popularity of the apple over other fruits consists in its greater usefulness as a food product, and in this respect it has found a multitude of uses, not only for domestic service, but also for the manufacture of evaporated fruit, jelly, cider, vinegar, and other products too numerous to mention. The superior keeping qualities of the apple render it especially adapted to exportation, and its hardiness of growth enables it to thrive under great extremes of climatic and other conditions.

According to the last census of 1890, the production of apples in the United States for the year 1889 amounted to 143,105,689 bushels. In order of production Ohio ranked first among the States, producing 13,789,278 bushels, and Pennsylvania tenth with 7,552,710 bushels. Pennsylvania although ranking tenth in the list, nevertheless, contains some of the best apple-producing land in the United States. The basin of the Ohio river appears to be the "Great Apple Region," and that part of Pennsylvania which falls within its limits is equal to any other apple growing region of the country in point of productiveness.

The ten counties of Pennsylvania leading in the production of apples for the year 1889, according to the last census, are the following:

County.	Bushels of Apples for 1889.
1. Allegheny,	597,638
2. Butler,	449,622
3. Washington,	403,368
4. Westmoreland,	349,281
5. Armstrong,	288,010
6. Bucks,	283,294
7. Beaver,	271,490
8. Mercer,	262,356
9. Bedford,	237,490
10. Greene,	205,459

All of the above counties with the exception of Bucks and Bedford are included in the "Great Apple Region" just mentioned. A variety of causes may contribute towards rendering this region more productive, as regards apples, than other sections of the country. It may be due to the fact that there is a greater amount of land in this section available for the planting of orchards, owing to the less mountainous character of the country; it is also quite possible that we have in this region some peculiar conditions (either physical or chemical) of the soil which tend towards securing a fuller development and a greater yield of fruit.

PART I. THE APPLE.

The Apple Considered Botanically.

The apple (*Pyrus Malus*) belongs to the Pome class of fruits, of which it may be considered the chief and most typical representative. It is a fleshy, succulent fruit, whose principal bulk, consisting of the edible portion or that part outside the core, is produced by an excessive development of the calyx of the apple-blossom; this change begins immediately after the pollination of the flower and, if nothing prevents, will continue until the apple has reached its normal size. During this period of growth a large quantity of nutritive matter must be supplied to the young fruit, both for the purpose of building up new tissue and for the purpose of storing the growing cells. For the supply of this there are two principal sources, viz: the roots and leaves of the tree; the roots supply to the fruit its water and mineral constituents while the leaves furnish the organic or vegetable parts of the apple. The manner in which these changes take place will be described under the "Chemistry of the Growth of the Apple."

The Chemical Composition of the Apple.

The chemical composition of the flesh of the average apple is represented in the following table. The percentages of the different constituents given are derived from analyses made by the writer upon different varieties of apples; only such apples as were perfectly ripe, sound, and unwilted, were selected in making this computation. To secure the proper effects of after-ripening, the apples were not examined immediately after picking, but were allowed to remain from one to two months in a cool cellar before being analyzed. It must be remembered that these results, being a general average, are only approximate; considerable variation from the figures given may be noticed in the case of any particular variety as subsequent analyses will show.

Table I.

(Showing the chemical composition of the flesh of the average apple.)

Inorganic.	
Ingredient.	Percentage.
Water,	84.00
Ash,	0.30

Organic.

Invert sugar (Dextrose and Levulose),	8.00
Cane sugar or sucrose,	4.00
Starch,	0.00
Cellulose,	0.90
Lignin,	0.40
Pentosans,	0.50
Pectin matter,	0.40
Malic acid, free,	0.60
Malic acid, combined,	0.20
Oil or fat,	0.30
Protein,	0.10
Undetermined (tannic acid, etc.),	0.30
Total,	100.00

The chemical nature of each of the above constituents merits a brief description.

Water.—This ingredient makes up by far the greater part of the apple. Its percentage usually ranges from eighty-two to eighty-six, though in some cases it may go below eighty or even as high as eighty-eight, the quantity depending upon the variety of fruit, time of picking, method of storing and other conditions. The juiciness and succulent quality of the apple are due entirely to its content in water. A considerable amount of moisture may escape through the skin of an apple by evaporation, especially if the fruit is stored for any length of time in too dry or warm a place; the percentage of water in such apples will of course be considerably below the normal.

Owing to the well-known solvent character of water, the greater part of the other ingredients of the apple—including the sugar, acid, pectin, and over ninety per cent. of the ash—exist not in the solid form but in aqueous solution, as is shown by analysis of the juice pressed from the grated fruit.

Ash or Mineral Matter.—If the pulp of an apple be dried in a suitable dish until all the water is expelled, and the residue be burned, all the organic matter will be destroyed and only the mineral substances or ash will remain. The quantity of ash thus left, after burning the pulp of an apple, is very small, usually making up only from 0.2—0.4 per cent. of the total amount of substance.

The chemical composition of the mixed ashes from many varieties of apples, according to an analysis made by the writer, is shown from the following table.

Table II.

(Showing the chemical composition of apple ashes.)

Ingredient.	Percentage.		Ingredient.	Percentage.
Potash (K_2O),	55.94	Equivalent to,	Pottassium carbonate (K_2CO_3),	67.85
Soda (Na_2O),	0.31		Pottassium phosphate (K_3PO_4),	14.55
Lime (CaO),	4.43		Sodium chloride ($NaCl$),	0.60
Magnesia (MgO),	3.73		Calcium sulphate ($CaSO_4$),	4.52
Oxide of iron (Fe_2O_3),	0.95		Calcium oxide (CaO),	2.57
Oxide of aluminum (Al_2O_3),...	0.80		Magnesium phosphate ($Mg_3P_2O_8$),	6.97
Chlorine (Cl),	0.39		Magnesium oxide (MgO),	0.59
Silica (SiO_2),	0.40		Ferric oxide (Fe_2O_3),	0.95
Sulphuric acid (SO_3),	2.66		Aluminum oxide (Al_2O_3),	0.80
Phosphoric acid (P_2O_5),	8.64		Silica (SiO_2),	0.40
Carbonic acid (CO_2),	21.60			
	99.90			
Deduct oxygen equivalent to Cl,	.09			
Total,	99.81		Total,	99.80

While the above analysis shows that the ashes of apples contain a considerable quantity of carbonate of potassium and a small amount of the oxides of calcium and magnesium, the statement should be made that these compounds do not exist in the fruit itself, inasmuch as the reaction of the latter is uniformly acid. The various bases which appear in the above analysis as oxides and carbonates exist in the apple, for the most part, in combination with malic acid as malates.

The mineral matter of the apple, though small in quantity, is nevertheless, a factor of considerable importance in the impoverishment of the soil in orchards as will be shown later.

The Sugars.—These are the most valuable of all the constituents found in the apple, and next to water, the most abundant. To the presence of these substances the apple owes its chief nutritive properties, and from the sugars contained in its pressed juice, the alcohol of cider and the acetic acid of vinegar are ultimately derived by fermentation. The quantity of sugars in the apple varies greatly, both according to the age and the variety of the fruit, the percentages usually ranging between twelve and fourteen. In analysis the sugars of the apple are generally classified as invert sugar and sucrose. The invert or direct reducing sugar is not a simple substance however, but a mixture of two other sugars, dextrose and levulose, in varying proportions.

Dextrose, or ordinary grape sugar, has the chemical formula $C_6H_{12}O_6$. It is easily crystallizable, possesses a slightly sweetish taste and in solution rotates the plane of polarized light to the right.

Levulose, or fruit sugar, possesses the same chemical formula as dextrose, but differs from it greatly in respect to chemical and physical properties. It is crystallized only with some difficulty; it possesses

a distinctly sweet taste and rotates the plane of polarized light strongly to the left. It is to the prevalence of levulose, therefore, that cider and other apple products owe their strongly marked laevo-rotatory power.

Sucrose, or ordinary cane sugar, has the chemical formula $C_{12} H_{22} O_{11}$. It is very easily crystallized, possesses an intensely sweet taste familiar to every one, and rotates the plane of polarized light strongly to the right. By the action of acids and certain ferments sucrose is converted into equal molecules of dextrose and levulose.

Starch.—This is a complex substance having the chemical formula $(C_6 H_{10} O_5)_n$. It is found in the cells of many plants, particularly in the seeds and grain, in the form of microscopic granules. The percentage of starch in apples varies entirely with the age of the fruit; in green apples it may amount to five per cent. or more, while in the completely ripened fruit it is altogether wanting. The presence of starch in an apple may be easily determined by testing some of the grated fruit with iodine tincture; if starch is present the pulp will be stained a distinct blue. This test is sometimes employed in European countries by fruit growers, the absence of any coloration with iodine indicating the complete ripeness of the apple.

The granules of apple starch, as viewed through the microscope, are globular in form, being more or less marked with a linear depression. Their average size, as determined from a large number of measurements made by the writer, is .009 millimeter (.00035 inch), the range being from .004 to .018 millimeter (.00016 to .00071 inch).

By pressing the grated pulp of green apples in a muslin bag with repeated quantities of water, nearly all of the starch can be washed out, and by allowing the washings to stand over night, the starch will settle out completely. The liquid above the starch may then be poured off, leaving the latter in condition for examination. The substance thus obtained possesses all the properties characteristic of ordinary corn or potato starch, differing from the latter, however, when seen under the microscope, both as to size and shape of granules. When heated with water, apple starch swells up enormously in bulk, forming a gelatinous party mass, thus behaving in a manner similar to other well known forms of starch. The starch of apples is very easily reacted upon by acids and certain ferments, such as diastase, being converted thereby into soluble sugars.

The marc of apples consists of the insoluble matter left after washing the pulp with large quantities of water and makes up usually from 1.60 to 2.00 per cent. of the flesh of the apple. It is composed almost entirely of cellulose, with its closely allied lignin bodies, and of certain substances of a hemi-cellulose nature comprising the pentosans. While of little nutritive value these constituents of the marc are of the greatest importance physiologically, in that they constitute the

material which makes up the walls of the cells, these being the minute receptacles or reservoirs of the apple, which contain the sugars and other substances in solution.

Cellulose.—This body has the same general formula as starch ($C_6 H_{10} O_5$)_n, but is much more complex in its structure than the latter substance; the exact molecular formula of both these bodies is at present unknown.

Cellulose may be obtained in quite pure condition by boiling the marc of apples with successive portions of dilute acid and alkali. The substance thus obtained is of a creamy white color, light and flakey, and makes up about one-half the total marc or from 0.80 to 1.00 per cent. of the flesh of the apple.

Lignin.—The exact chemical composition of this substance is unknown. It is closely connected with cellulose both as regards its nature and derivation, but differs somewhat from the latter in its chemical properties, being less resistant than the latter towards certain reagents, such as alkalies and alkaline sulfites. Its percentage in the marc of apples may be approximately determined by estimating the amount of matter removed by the boiling alkali after the acid treatment in the cellulose determination.

Pentosans.—These bodies are closely related to both cellulose and lignin, the view of many chemists being that these three constituents of vegetable fiber are not separated from one another but exist in some combined form.

The pentosans have the chemical formula $C_5 H_8 O_4$; they are the least resistant to chemical action of any of the fiber constituents, being easily attacked when boiled with dilute acids. One distinguishing feature of the pentosans is their property of yielding furfural when distilled with dilute hydrochloric acid; upon this fact is based the method for their determination. The pentosans constitute from 25 to 30 per cent. of the dry marc of apples or about 0.50 per cent. of the original pulp.

Pectin.—Green apples contain more or less of an insoluble substance called pectose, which is probably a cellulose derivative, and this, through the action of a ferment during the process of ripening, is converted into the soluble substance pectin.

Pectin is precipitated from its solutions by alcohol upon which property is based the method for its determination. It is present in the flesh of apples in amounts varying from 0.2 to 0.6 per cent. While of little importance as regards nutritive value, it renders a peculiar and distinctive service in the preparation of apple and cider jellies—the property which these materials have of setting or gelatinizing being due entirely to the small amount of pectin matter present.

Malic Acid.—It is to the presence of this body that the sour or acid taste of apples is due. Malic acid has the chemical formula $C_4 H_6 O_5$;

its percentage in apples varies greatly according to age and variety, the range having been found to extend from 1.14 per cent. in a green apple to 0.48 per cent. in the same variety when ripe and from 0.19 per cent. in a sweet apple to 1.11 per cent. in a sour specimen. The sweetness of an apple is dependent upon the absence of malic acid rather than upon an excess of sugar, as is commonly supposed; sour apples are frequently found to contain more sugar than fruit of a sweeter kind.

The greater part of the malic acid of apples exists in the free condition; about one quarter of the total acid, however, occurs in combination with certain bases, principally potash, to form either acid or neutral salts. The quantity of such combined acid can be readily calculated from the alkalinity of the ash.

Oil or Fat.—This represents the material extracted from the dried pulp of apples by means of ether or benzene. But very little fat is found in the flesh of the apple, the tendency being for this substance to accumulate in the seeds; the percentage of fat in the edible portion of apples was found to average 0.28.

Protein.—This is the nitrogenous matter of the apple; it constitutes, however, but a very small percentage of the fruit. The amount of nitrogen in the edible portion of the apple varies from 0.01 to 0.02 per cent., and the albumenoids or protein, as calculated from this, would vary from 0.06 to 0.13 per cent. Nitrogen is found in greater abundance in the seeds and core of apples, and owing to this fact the percentage of nitrogen in the whole apple is somewhat greater than in the fleshy part alone, the amounts varying from 0.04 to 0.08 per cent.

No determinations were made of the other miscellaneous constituents, such as gum, dextrin, fruit esters, tannic acid, etc., which occur in apples in small amounts; these bodies were simply classified together in the undetermined residue.

The fruit esters are worth mentioning, for although occurring in but minute quantities, it is to them that the apple owes its pleasant aromatic odor and taste. The principal ester of the apple is amyl valerate, and the artificial apple essences are flavored mainly with this compound.

The tannic acid, which is present in apples in small amounts, is perhaps a disadvantage rather than a benefit. It is supposed that, when apples are freshly cut, the oxidation of the tannic acid by means of a ferment causes the flesh of the fruit to become brown; the coloration which cider undergoes after pressing is similarly explained. In the manufacture of evaporated apples this oxidation and consequent discoloring is prevented by exposing the fruit to the fumes of sulphurous acid.

The Chemistry of the Growth of the Apple.

But little is known of those complex chemical changes, which take place within the apple during the period of its development. It has been sufficiently determined that the organic matter which makes up the apple is primarily formed in the leaf, being the result of the action of sunlight upon the chlorophyll grains, whereby the carbonic acid absorbed from the air through the leaf pores and the water taken up from the soil through the roots are made to unite. Starch is one of the principal results of this combination and its presence can be detected in all chlorophyll grains, if the examination be made by daylight. During the night the starch granules which were formed in the chlorophyll undergo solution and disappear; this solution of the starch no doubt takes place in the daytime also, but is not directly observable, owing to the fact that new starch is continually being formed. In this process of solution, which is probably effected through the agency of a ferment, the starch is changed into some form of sugar, which is then conveyed from the leaf to the various points of use. In the fruit a considerable part of this sugar is reconverted into starch through the agency of certain amylogenic or starch forming bodies. The starch which is thus reformed is not stored up as reserve material, however, but is destined to undergo still further transformations.

The following analysis of a Baldwin apple made at four different periods will illustrate the nature of some of these changes.

Table III.

(Showing the composition of a Baldwin apple at different periods.)

Period.	Date, 1899.	Condition	Water.	Solids.	Invert sugar.	Sucrose.	Total sugar.	Total sugar after in- version.	Starch.	Free malic acid.	Ash.	Sugar coefficient.
I.	Aug. 7,	Very green...	81.53	18.47	6.40	1.63	8.03	8.11	4.14	1.14	0.27	47.16
II.	Sept. 13,	Green,	79.81	20.19	6.46	4.05	10.51	10.72	3.67	.....	.....	53.10
III.	Nov. 15,	Ripe,	80.36	19.64	7.70	6.81	14.51	14.87	0.17	0.65	0.27	75.71
IV.	Dec. 15,	Over-ripe, ...	80.30	19.70	8.81	5.26	14.07	14.35	.....	0.48	0.28	72.84

An increase of over six per cent. is noted in the total amount of sugar as found in the first and third periods of analysis, and this increase is shared by each of the constituent sugars, the sucrose, however, being formed in much the larger quantity. With this increase in sugar we notice a marked decrease in the percentage of starch—a coincidence which leads to the supposition that the starch may serve

as a parent substance in the formation of sugar in apples, and that sucrose is the first product formed. In the germination of seeds starch is converted by the ferment diastase into the complex sugar maltose $C_{12}H_{22}O_{11}$, a formula identical with that of sucrose, so that the possibility of the starch of apples being converted into sucrose by a ferment is not improbable.

The sucrose of apples in its turn is very easily affected both by acids and ferments, being converted into dextrose and levulose, and in this way a considerable part of these last named sugars find their origin. This is further shown by the decrease of sucrose in Period IV, with the corresponding increase in the percentage of invert sugar.

As regards changes in other constituents between the different periods, the percentage of water does not appear to vary much either in one direction or another; a decrease in the percentage of acid is observed, however, throughout the experiment. This change has been observed in the ripening of all fruits, and has led to the supposition that the fruit acids are in some way connected with the formation of sugar. An increase is observed in the sugar coefficient up to Period III, the point of complete ripeness, after which time there is a falling off in this constant. The sugar coefficient, which represents simply the percentage of total sugar after inversion in the solid matter of the apple, has been found by the writer to be a very convenient means of comparison and is introduced into this and succeeding tables wholly for that purpose.

The starch no doubt plays another important part in the physiology of the growing apple besides that of sugar formation, viz: that of aiding in the building up of new tissue (cellulose). It is not known yet in just what manner this change is brought about; the process is not a simple conversion of starch into cellulose by means of an acid or ferment, as is the case with the conversion of starch into sugar; the change is of a vastly different order, being the result of certain vital processes acting within the living cell. In some mysterious way the conversion is brought about, the view of many being that for a time the starch is made a part of the living protoplasm by the transformation of which the complex cellulose molecule is ultimately derived.

The After Ripening and Storage of Apples.

After an apple has reached its fullest development as to size and weight, the influx of nutritive matter from without practically ceases; there is no formation of new starch granules, and the chemical changes which now take place are simply transformations of organic matter already existing within the apple. The fruit, having received its proper supply of nutriment from without, is henceforth independent of the tree which bears it. It may be picked and will ripen, just as

well as if allowed to remain upon the tree; in fact it is the consensus of opinion among fruit growers everywhere that this is the proper time for apples to be picked. It is agreed that apples which are gathered, as soon as the maximum size and weight have been attained, even while they are yet hard, and are then carefully stored, develop a much finer flavor and possess much better keeping qualities than if allowed to ripen upon the tree.

As to the proper method of preserving fruit after picking, a great variety of opinions prevail. It is impossible here to discuss the merits or demerits of the various systems in use; a few general statements may, however, be made.

Apples should not be stored in too dry a place; the skin of the apple is quite porous in texture and a large amount of moisture will escape by evaporation, the result being that the fruit has a wilted and shriveled appearance. Neither should apples, which are to be kept for any great period of time, be stored in too warm or too moist a location; these conditions will hasten the ripening of the fruit, which should be retarded as much as possible, if the apples are to be kept until spring. Moisture and warmth are also conditions especially favorable for the development of those fungi which produce rot. Nor should apples be kept in a place which is subject to sudden and extreme changes of temperature; alternate freezing and thawing are especially bad for apples, as both flavor and keeping quality are injured thereby.

Some form of cold storage is the best manner of preserving apples, and wherever possible this is the method which should be practiced; fruit kept in this way will retain its fresh and crisp appearance for many months and the loss from rotting will be small.

The following excellent rules by Thomas for "strict observance in keeping fruit" may be presented in this connection.

"1. Let the temperature be kept as near the freezing point as practicable.

"2. Keep the temperature as uniform as possible, as an occasional warm draught hastens decay.

"3. Exclude air-currents of any kind not required to maintain a uniform degree of cold; hence drawers or covered boxes are better than open shelves.

"4. Keep all odors away from the fruit, especially such odors as come from badly kept cellars."

The Chemistry of After-Ripening.

The chemical changes which take place in an apple during the period of storage are at first simply a continuation of those changes which went on during its period of growth, consisting principally of the conversion of the residual starch of the apple into sugar. With

the complete conversion of its starch, the apple, in a chemical sense, may be considered ripe; the amount of sugar present is then at its highest, as is shown by the sugar coefficient having attained its maximum. This condition of affairs is well illustrated in the Third Period of Table III, which represents the composition of a Baldwin apple one month after picking. Here a culmination of the constructive forces previously at work within the apple is attained, henceforth there is a retrogression, as is shown by the lowering of the sugar coefficient in Period IV.

To better understand the nature of the chemical forces at work in the after-ripening of fruit, the following experiment was performed upon a sample of Sweet Vandevere apples. The apples were obtained from the fruit house of Wm. P. Fisher, of Unionville, Pa.; a part of them were analyzed at once after taking from cold storage with the results expressed in Period I of the following table. Another portion of the apples, after being weighed, were kept in a dark cupboard at the ordinary temperature for eighteen days, when, after weighing again to determine loss from evaporation, they were also analyzed with the results given in Period II.

Table IV.

(Showing changes in composition of Sweet Vandevere apples during after ripening.)

Period.	Date, 1899.	Water.	Solids.	Invert sugar.	Sucrose.	Total sugar.	Total sugar after inversion.	Malic acid.	Ash.	Sugar coefficient.	Loss from evaporation.
I,	Nov. 27,	82.25	17.75	8.81	3.85	12.66	12.86	0.26	0.30	72.45	.....
II,	Dec. 15,	81.65	18.35	9.61	3.18	12.78	12.95	0.26	0.34	70.57	6.66

From the above analyses it appears that the apples, during the eighteen days after removal from storage, lost 6.66 per cent. in weight. An increase is noted in the per cent. of invert sugar with a corresponding decrease in the per cent. of sucrose, showing that a gradual inversion of the latter is taking place. A slight gain is observed in the percentage of total sugar; this gain is more apparent than real, however, and is, simply the result of a concentration of the sugars in the apple from evaporation of water. If the 12.95 per cent. of total sugars after inversion in Period II be calculated to the original weight of apples, there would be found only 12.09 per cent. or a decrease of 0.77 per cent. from the amount originally present.

Knisch, who has made some very exhaustive studies upon the

after-ripening of apples finds that this loss in sugar, after correcting for evaporation, may amount in some cases to over four per cent. This loss, which is a very serious factor in the deterioration of fruits, results from a decomposition of the sugar into lower compounds—water and carbonic acid being the ultimate products formed.

This loss or reversion of sugar in reality marks the first beginnings of decay and, though the apple may still be sound, it serves to indicate that a process of dissolution has begun.

Analyses of Twenty-five Different Varieties of Apples.

In Table No. V analyses are given of twenty-five leading varieties of apples. Determinations were made of water, solids, sugars, acid and ash, these being the most important of the constituents found in the apple. Analyses were not made, with the exception of the early summer varieties, until from one to two months after the fruit was gathered, in order to insure the conversion of the residual starch into sugar. The samples after picking were kept in bags in a cool cellar until analyzed.

Table V.

(Showing the chemical composition of twenty-five leading varieties of apples.)

Number.	Variety.	Season.	Owner and Locality of Orchard.	Number of apples taken for analysis.	Water.	Solids.	Invert sugar.	Sucrose.	Total sugar.	Total sugar after In- version.	Free malic acid.	Ash.	Sugar coefficient.
1	Red Astrachan,	Summer,	F. E. Tuttle, State College, Pa.,	10	84.70	15.30	6.67	3.53	10.20	10.38	1.11	0.37	67.84
2	Early Harvest,	Summer,	College Orchard, State College, Pa.,	10	83.82	16.18	7.24	3.84	11.08	11.28	0.87	0.31	69.72
3	Yellow Transparent,	Summer,	Geo. C. Butz, State College, Pa.,	4	86.17	13.83	7.84	2.05	9.89	9.94	0.84	0.27	71.87
4	Early Strawberry,	Summer,	College Orchard, State College, Pa.,	10	84.42	15.58	5.34	4.11	9.45	9.66	0.76	0.28	62.00
5	Sweet Bough,	Summer,	College Orchard, State College, Pa.,	6	85.18	14.82	7.51	2.98	10.49	10.64	0.10	.....	71.79
6	Butter-sweet,	Autumn,	College Orchard, State College, Pa.,	6	85.70	14.30	7.97	3.62	11.53	11.78	0.38	.....	82.38
7	Fall Rambo,	Autumn,	College Orchard, State College, Pa.,	6	83.86	16.14	6.60	4.92	11.52	11.78	0.61	0.25	72.99
8	Baldwin,	Winter,	College Orchard, State College, Pa.,	6	80.36	19.64	7.70	6.81	14.51	14.87	0.65	0.27	75.71
9	King,	Winter,	College Orchard, State College, Pa.,	3	84.30	15.70	7.94	3.87	11.81	12.01	0.48	0.27	76.50
10	Golden Russet,	Winter,	College Orchard, State College, Pa.,	10	76.64	23.36	11.75	11.75	16.54	16.79	0.70	0.32	71.87
11	Greening,	Winter,	College Orchard, State College, Pa.,	6	83.20	16.80	7.11	5.27	12.38	12.66	0.68	0.36	75.36
12	Ben Davis,	Winter,	College Orchard, State College, Pa.,	6	85.04	14.96	6.90	3.69	10.49	10.68	0.55	0.38	71.39
13	Northern Spy,	Winter,	College Orchard, State College, Pa.,	4	82.43	17.57	8.92	4.29	13.21	13.44	0.67	0.33	76.49
14	Northern Spy,	Winter,	College Orchard, State College, Pa.,	3	82.94	17.06	9.44	3.25	12.69	12.86	0.53	0.24	75.38
15	Spitzenburgh,	Winter,	Geo. L. Watson, Clyde, N. Y.,	3	80.02	19.98	8.92	5.45	14.67	14.98	0.86	0.29	74.98
16	Spitzenburgh,	Winter,	College Orchard, State College, Pa.,	2	82.54	17.46	8.19	5.06	13.25	13.52	0.62	0.30	77.48
17	Twenty Ounce,	Winter,	Geo. L. Watson, Clyde, N. Y.,	2	86.54	13.46	7.27	2.60	9.87	10.01	0.45	0.17	74.19
18	Jonathan,	Winter,	T. W. Way, State College, Pa.,	8	85.28	14.72	7.40	3.63	11.03	11.22	0.52	0.22	76.22
19	Canada Reinette,	Winter,	T. W. Way, State College, Pa.,	6	84.30	15.70	6.60	3.74	10.34	10.54	0.51	0.24	73.29
20	Rambo,	Winter,	T. W. Way, State College, Pa.,	8	84.30	15.70	10.32	1.74	12.06	12.15	0.36	0.23	77.39
21	Newtown Pippin,	Winter,	Wm. P. Fisher, Unionville, Pa.,	6	82.39	17.61	6.36	6.13	12.49	12.81	0.80	0.27	72.74
22	Evall,	Winter,	Wm. P. Fisher, Unionville, Pa.,	6	84.36	15.64	8.13	2.64	10.77	10.91	0.99	0.26	69.76
23	York Imperial,	Winter,	Wm. P. Fisher, Unionville, Pa.,	6	82.90	17.10	8.65	4.33	12.98	13.21	0.46	0.22	77.25
24	Fallowater (Tulpanocken),	Winter,	Wm. P. Fisher, Unionville, Pa.,	6	84.69	15.31	8.51	3.08	11.59	11.75	0.32	0.22	76.75
25	Yellow Bellflower,	Winter,	Wm. P. Fisher, Unionville, Pa.,	6	81.68	18.32	8.43	4.65	13.08	13.32	0.74	0.34	72.71
26	Sweet Vandevere,	Winter,	Wm. P. Fisher, Unionville, Pa.,	6	82.25	17.75	8.81	3.85	12.66	12.86	0.26	0.26	72.45
27	Bedford Red,	Winter,	Wm. P. Fisher, Unionville, Pa.,	4	84.96	15.04	7.49	3.50	10.99	11.08	0.65	0.23	73.67
	Average of all, .....	.....	.....	.....	83.57	16.43	7.92	3.99	11.91	12.12	0.61	0.27	73.76

The above analyses cannot be considered typical in any instance; fruits of the same variety may differ in composition, as is shown in cases where varieties from different localities were analyzed, as with the Northern Spy and Spitzenburgh in the preceding table. A large number of analyses of fruit from many localities and during a period of several years can alone determine as to the typical composition of any variety.

The summer apples in the above table were analyzed immediately after picking, and in all cases contained considerable amounts of starch; this would explain the lower sugar coefficient of the early varieties. Particularly noticeable is the sugar coefficient of No. 6, which is five per cent. higher than that observed for any other variety. The high percentages of solids and sugar in No. 10 are also worthy of attention; the writer believes this to be due to the very porous character of the skin of russet apples, which would permit a greater loss from evaporation than with other varieties with a consequent greater concentration of solids. It would be interesting to determine whether or not this peculiarity is shared by all members of the russet family.

The Depletion of Soil by Apples.

Reference has been made to the fact that in the growth of fruit, small quantities of mineral matter are being constantly removed from the soil. These mineral constituents play an important part in the physiological development of the apple—the growth of the fruit requiring the presence of certain valuable soil ingredients, the same as other crops. The removal of a large crop of apples from an orchard year after year, means the removal also of a considerable supply of valuable plant food, and unless this is in some way restored the soil of the orchard will in time become exhausted. Bailey states that “the depletion of land by fruit trees is more serious than by annual crops, from the fact that plant-foods are locked up for many years in the trunks and branches of the trees, whilst a large part of the fertilizing constituents in common crops returns to the soil each year.”

Of the various ingredients removed from the soil by the growth of plants or trees, nitrogen compounds, phosphoric acid, and potash are the only ones in danger of becoming exhausted, the other constituents being usually present in superabundance. Nitrogen, phosphoric acid, and potash in their various forms are therefore the only materials generally supplied as plant food in fertilizers.

The percentages of nitrogen, phosphoric acid and potash in the whole apple, with the corresponding weight of material in pounds removed by the average annual crop per acre, according to the independent determinations of Schutt and Roberts, are as follows:

	Present in Whole Apple.		Pounds Removed Yearly Per Acre.	
	Schutt.*	Roberts.†	Schutt.*	Roberts.†
Nitrogen,	.043	0.13	8.95	33.2
Phosphoric acid,	.025	0.01	5.23	2.5
Potash,	.155	0.19	32.81	48.5

The average percentages found by the writer coincide very closely with the values of Schutt; they are given below together with the cash value of the different fertilizing ingredients.

Table VI.

(Showing cash value of fertilizing ingredients in a single crop from one acre of orchard.)

	Per cent. in whole apple.	Pounds removed annually per acre. (400 bushels of apples weighing 20,000 pounds.)		Cash value.
Nitrogen,	.059	11.8	@14c	\$1 65
Phosphoric acid,	.027	5.4	@ 5c	27
Potash,	.168	33.6	@ 4½c	1 51
Total cash value of fertilizing ingredients,				\$3 43

The above does not represent however the total amount of fertilizing ingredients removed from an acre of orchard land by the growth of a single crop of apples. A large amount of plant food enters each year into the composition of the leaves and wood of the tree and this should also be taken into account. Enough has been said, however, to show that there exists the same necessity for applying fertilizers to orchards as to any of the annual crops.

There is not room here for discussion as to the kind and quantity of fertilizers which should be applied to apple trees. Conditions vary so in different regions that it is impossible to tell what would be best in every instance; the question is one which every fruit grower must answer for himself.

*Experimental Farms Report, Ottawa, Can., 1894, p. 167.

†Cornell Experiment Station, N. Y., Bulletin 103.

PART II.—APPLE PRODUCTS.

I. EVAPORATED APPLES.

One of the greatest problems which faces the fruit grower is the disposal of his unmerchantable fruit. After picking and sorting the apples which are suitable for barreling, a large residuum usually remains wholly unfit for market purposes either from its being bruised or misshapen, or from its being made up of unpopular varieties. The percentage of apples which are thus unsalable has been estimated to make up nearly one-fourth of the total annual yield; the utilization of such unmerchantable fruit is, therefore, a question worthy of consideration.

Importance of the Apple Evaporating Industry.

The manufacture of evaporated apples is one of the principal as well as one of the most profitable means of disposing of this otherwise unsalable quality of fruit. It is an industry of considerable importance in the apple growing districts of New York, and has also made its way into many regions of Pennsylvania. The growing importance of this industry may be seen from the fact, that during the few years past more apples have been evaporated for the foreign trade than have been directly exported as whole fruit.

Best Varieties for Evaporating.

The early summer apples seem less adapted for evaporating than the fall and winter varieties, giving neither the yield nor quality of product; the reason for this no doubt consists in the lower sugar coefficient of the early varieties as has already been pointed out. The general experience is that the Russets, Pippins, Spitzenburgh, Baldwin, Ben Davis, Greening, and Northern Spy are among the varieties best adapted for evaporating. The apples richest in solids would naturally give the highest percentage of evaporated fruit, so that, according to the analyses of different varieties previously given, the Russet, Spitzenburgh and Baldwin would give the best returns to the evaporator. This view is sustained in actual work as is shown from the following table,* which is the result of a practical experiment performed in an evaporating plant upon a large quantity of fruit. The percentage of solids corresponding to each variety is appended from Table V.

*U. S. Department of Agriculture Report, 1886, p. 353.

Table VII.

(Showing ratio between yield of evaporated fruit and per cent. of solids.)

Variety.	Weight of evaporated fruit per bushel of apples.	Solids from Table V.
Roxbury Russet,	8½ to 9 pounds.	*23.36 per cent.
Spitzenburgh,	6½ to 7 pounds.	19.98 per cent.
Baldwin,	6 to 7 pounds.	19.64 per cent.
Greening,	5½ to 6½ pounds.	16.80 per cent.
King,	5½ to 6 pounds.	15.70 per cent.
Twenty-Ounce,	4 to 5½ pounds.	13.46 per cent.

Method of Manufacture.

In the process of manufacture as generally carried out, the fresh fruit is first pared and cored by machines and then trimmed to remove all bruises and specks. The apples thus prepared are immediately exposed for about an hour to the fumes of burning sulphur—a process called bleaching or color-setting, the object of which is to prevent the discoloring through oxidation, which apples undergo when cut and exposed to the air. The fruit is then sliced, after which it is carried to the evaporator, where it is left until the proper degree of dryness is secured. The rate of evaporation depends wholly upon the temperature, varying from a few hours to several days; there are many kinds of evaporating devices, from the ordinary kiln to the steam-heated tower, working at all temperatures from 95 degrees to 250 degrees Fahrenheit. The fruit after removing from the evaporator is allowed to remain in heaps for several weeks in order to “ripen” after which it is ready for packing.

Chops.—The small imperfect apples which are not suited for making good evaporated fruit are often sliced without paring or coring and then evaporated in the usual way. This product is called “chops” and is exported largely for the purpose of making champagne and brandy, and for fortifying wines. The parings, cores, trimmings, etc., which accumulate in large quantities are utilized in a similar way; they are also exported in quantity being used for making jelly and cheap champagnes.

Sun-dried Fruit.—The method of preparing evaporated fruit by sun-drying is practiced to a considerable extent in some sections of the country. Although requiring little or no outlay for machinery, it is an unsatisfactory and in the end an expensive method of drying apples,

*Golden Russet.

since the product is greatly inferior to that obtained by the rapid process, being discolored and frequently moth-blown. Such methods are no longer profitable in the light of modern enterprise, and in apple growing regions farmers will make more money by setting up evaporators on the co-operative plan.

"Schnitz."—A very large quantity of apples are evaporated in the homes of farmers in all parts of Pennsylvania. While this product is made mostly for the purpose of home consumption, a large quantity of it finds its way into the city markets, as it is preferred by many to machine made fruit. This home-made evaporated fruit is most generally known in Pennsylvania under the name of "schnitz," from a Pennsylvania German word meaning slicings or cuttings. The product is very rarely sulphured and so is more discolored than the evaporated article. The apples after being pared and sliced are simply dried in pans or trays upon the back of the stove or in the oven when the fire is low. A number of small portable evaporators are at present being manufactured for making home evaporated fruit; they are adapted for use upon an ordinary cook stove and after filling the trays require but little care or attention.

The Chemical Composition of Evaporated Apple Products.

Experiments conducted by Richards* of the United States Department of Agriculture in 1885, show that practically no change in composition is undergone by apples in the process of drying beyond the loss of a large amount of moisture. In other words the original solids of the apple are simply present in a more highly concentrated form. These results by Richards are wholly confirmed by the work of the writer, as the following analyses will show.

Table VIII.

(Showing chemical composition of evaporated apple products.)

Number.	Moisture.	Solids.	Invert sugar.	Sucrose.	Total sugar.	Total sugar after inversion.	Free malic acid.	Ash.	Protein.	Marc.	Undetermined fat, etc.	pectin.	Sugar coefficient.
1.....	28.88	71.12	35.68	15.31	50.99	51.80	4.10	1.13	0.92	7.54	6.44		72.83
2.....	26.34	73.66	29.92	22.72	52.64	53.84	4.05	1.07	0.81	8.69	6.40		73.09
3.....	9.35	90.65	42.84	19.16	62.00	63.00	3.75	1.74	1.48	15.24	6.44		69.49

Number 1 was a sample of evaporated apples made at North Rose, Wayne Co., N. Y.

Number 2 was a sample of evaporated apples, put up in 1 lb. packages and made at Sodus, Wayne Co., N. Y.

Number 3 was a sample of home-dried apples or "schnitz," made by Henry Shreffler, State College, Pa., for his own family use.

*U. S. Department Agricultural Report, 1886, p. 350.

Correcting the results of Table VIII to an apple containing 16 per cent. solids we would have for the principal ingredients:

Number.	Product.	Invert sugar.	Sucrose.	Free malic acid.	Ash.	Protein.	Marc.
1	Evaporated apples,	8.03	3.44	0.92	0.25	0.21	1.70
2	Evaporated apples,	6.50	4.94	0.88	0.23	0.18	1.89
3	Home-dried apples,	7.37	3.30	0.65	0.30	0.25	2.62

These results show a very close agreement with values previously given for the composition of the flesh of whole apples. The calculated percentages of protein are slightly higher than any results found by the writer for the flesh of apples alone; this excess is attributed to the presence of fragments of the more highly nitrogenous carpel envelope, due to defective coring.

An analysis of the ashes of the two evaporated samples in the above table showed two important particulars in which such factory made products may differ from whole apples. This can be seen from the following table:

Table IX.

(Showing percentage of zinc oxide and sulphuric acid in ashes of evaporated apples.)

	Zinc oxide (ZnO).	Sulphuric acid (SO ₃).
Ash of evaporated apples, I,	1.23	4.89
Ash of evaporated apples, II,	1.50	6.09
Ash of whole apples, .....	.....	2.66

The amount of zinc oxide in the original evaporated fruit would be .0139 per cent. for Sample I and .0160 per cent. for Sample II. Many samples of evaporated apples examined in the laboratory of the United States Department of Agriculture were found to contain zinc oxide in amounts varying from nothing or a mere trace up to .0242 per cent.

The Zinc Question.

The zinc, which is so commonly present in evaporated fruit, comes wholly from the galvanized iron-wire tray-bottoms of the evaporator; a part of it no doubt consists of small metallic particles which were chipped off mechanically in stripping the evaporated fruit from the trays; the greater part, however, is absorbed through the solvent action of the acids of the apple upon the zinc coating of the wires. How easily this may be done is shown from the fact that many of the slicings of evaporated apples No. II, in the preceding table, were marked with the prints of wire netting, showing that the apples had been evaporated in the closest contact with the galvanized metal.

Large consignments of evaporated fruit from this country have been frequently condemned abroad simply because they contained zinc. It is very doubtful if the minute quantities of zinc found in evaporated fruit would ever produce harmful effects. The best plan, however, is to err always on the side of safety, and to remove all possible sources of contamination some substitute should be found for the galvanized tray-bottoms at present so generally employed.

Sulphuring and Its Effects.

The higher percentage of sulphuric acid in the ash of evaporated apples is no doubt the result of the sulphuring process, and this brings up another objection frequently raised against commercial evaporated fruit. This slight increase of sulphuric acid is not sufficient, however, to justify any apprehension. The demand of the trade is for a white evaporated product, and as the sulphuring process is the most satisfactory method of securing this result and is harmless if properly conducted, there does not seem sufficient reason for condemning it. The opinion of Dr. Wiley is worth quoting in this connection: "The fresh appearance of evaporated fruits secured by the moderate bleaching which has been described is, in my opinion, of value and fully justifies the process. It is only when the bleaching is overdone, or when it has been applied in excess to fruits already discolored and dried, that it can justly be condemned."

In some places instead of sulphuring, the apples, after paring, are dipped in baths of salt. This prevents discoloration, but does not secure the perfect whiteness which comes from the other process.

II. CIDER.

The Importance of the Cider Making Industry.

The manufacture of cider offers to the farmer and fruit-grower another most satisfactory means of disposing of unmerchantable fruit. It is impossible to form an exact estimate of the amount of cider which is manufactured yearly in the State of Pennsylvania, but from data supplied by various manufacturers of cider making machinery, the output each fall from the numerous presses throughout the State would appear to exceed greatly 10,000,000 gallons. This amount, which is a very conservative estimate, is sufficient evidence of the importance of cider making among the agricultural industries of the State.

Selection of Fruit.

The methods of manufacturing cider, as regards the grating and pressing of the fruit, are too well known to require explanation. To prepare good cider, some care is necessary in the selection of apples. Green or rotten fruit should never be employed; apples of the former kind make a cider that is deficient in sugar and turbid from suspended particles of starch, while rotten fruit is sure to impair the flavor of the extracted juice. Early apples make a much poorer quality of cider than the later fall and winter varieties, as subsequent analyses will show, a fact due to their lower content in sugar. A much better cider is made if apples are allowed to remain in heaps for a few weeks after picking, before going to the press; this will insure a thorough ripening of the fruit and a complete conversion of the starch, thus increasing the amount of fermentable sugar, which the expressed juice will contain, and rendering the latter also clear and bright. Fruit stored for after ripening should not be left too long, however, as there is then a danger of loss, as has already been explained, from the reversion of sugar.

Chemical Composition of Apple Juices.

The composition of the fresh juice, as it is obtained from various varieties of apples, is shown in Table X.

Table X.

(Showing the chemical composition of apple juices.)

Number.	Variety.	Season.	Specific gravity.	Solids.	Invert sugar.	Sucrose.	Total sugar.	Total sugar after In- version.	Free malic acid.	Ash.	Undetermined (pectin, etc.).	Rotation, 400 mm tube, Ventzke scale. De- grees to the left.
1	Red Astrachan,	Summer,	1.05317	12.78	6.87	3.63	10.50	10.69	1.14	0.37	0.77	23.72
2	Early Harvest,	Summer,	1.05522	13.29	7.49	3.97	11.46	11.67	0.90	0.28	0.65	24.32
3	Yellow Transparent,	Summer,	1.05020	11.71	8.03	2.10	10.14	10.24	0.86	0.27	0.44	.....
4	Early Strawberry,	Summer,	1.04949	11.81	5.47	4.21	9.68	9.90	0.78	0.24	1.11	19.24
5	Sweet Bough,	Summer,	1.04979	11.87	7.61	3.08	10.69	10.85	0.10	.....	.....	39.40
6	Baldwin, green,	Summer,	1.04832	11.86	6.96	1.63	8.59	8.68	1.24	0.31	1.22	36.16
7	Baldwin, ripe,	Winter,	1.07362	16.82	7.97	7.05	15.02	15.39	0.67	0.26	0.87	.....
8	Ben Davis,	Winter,	1.05389	12.77	7.11	3.85	10.96	11.16	0.46	0.28	1.07	49.00
9	Bellaflower,	Winter,	1.06270	14.90	9.06	4.32	13.38	13.61	0.58	0.23	0.66	33.26
10	Tulpahocken,	Winter,	1.05727	13.94	9.68	3.11	12.79	12.95	0.26	0.24	0.49	48.20
11	Unknown,	Winter,	1.05901	13.75	10.52	2.31	12.83	12.95	0.44	0.26	0.22	44.18

A great difference will be noticed in the composition of the juices from the summer and winter varieties, the latter containing on the average, about two and one-half per cent. more sugar. This fact explains the higher percentage in solids and the greater specific gravity of the juices from winter apples and also the increase in rotation of the plane of polarized light to the left, the latter circumstance showing that it is in levulose especially that the juices from winter apples are richer. The analysis of the juice from a green Baldwin revealed a marked deficiency in sugar, but a high percentage of acid.

The Fermentation of Apple Juice.

The alcoholic fermentation of fruit juices is produced by means of certain organized ferments or minute vegetable growths of the genus *Saccharomyces*, of which the ordinary yeast plant is the best known representative. In this fermentation process the sugar of the juice is changed into alcohol and carbonic acid, according to the general formula



or 100 parts sugar=51.11 parts alcohol and 48.89 parts carbonic acid.

In practice the above theoretical yield of alcohol is never realized, owing to certain secondary fermentative changes. The results of an unpublished experiment upon the fermentation of apple juice, performed by the writer at the Pennsylvania Experiment Station, show that about 47 parts of alcohol may be obtained from 100 parts of sugar after inversion, or about 92 per cent. of the theoretical yield. It should be stated that sucrose itself is not directly fermentable, but is first changed by means of the soluble ferment, invertase, which exists in yeast, into dextrose and levulose—these sugars being then convertible into alcohol and carbonic acid as shown above.

Methods of Conducting the Fermentation.

To secure the best results in the fermentation of apple juice the greatest care and cleanliness are necessary. Unfortunately too little attention has been paid to these points in the United States, the general opinion seeming to be that after a barrel has been filled with apple juice nothing more remains to be done, and that the fermentation will take care of itself.

In European countries more care is exercised in all particulars. The fresh juice or must is first run into large vats or fermenting tubs, which are kept in a building of quite uniform temperature. A fermentation begins at once due to the development of the yeast spores, which fall upon the surface of the must, as it lies exposed to the air. As fermentation progresses a large amount of impurity is carried to the surface

by the carbonic acid, which is developed, producing a head of scum; at the same time a sediment, consisting of yeast cells, gummy matter, etc., settles to the bottom. After this first or main fermentation the clear liquid is drawn off ("racking off") from between the surface scum and sediment into clean casks, which are then transferred to a cool cellar to undergo the second or still fermentation. The racking off must be done before any development of the acetic fermentation, the latter being very apt to follow the alcoholic unless care is taken; to prevent any such secondary fermentations the casks, into which the cider is received after the main fermentation, are kept quite full, with the bungs set loosely in.

At the conclusion of this second fermentation the cider is again racked off either into perfectly clean casks, which are filled full, the bungs being driven tightly in, or else filled into bottles, which are securely stoppered. Before bottling, cider is generally "fined," an operation performed by adding small amounts of isinglass, this substance causing a precipitation of the small quantities of albumenoid bodies, which sometimes remain in solution and which are so apt to injure the keeping qualities of the cider.

When manufactured as described above, cider will keep almost indefinitely, and no necessity will be found for the senseless custom of adding lime, soda, sulfite, salicylic acid or other substances to prevent souring. The flavor will also be greatly superior to that of ciders fermented according to the usual hap-hazard methods.

Experiments are at present being conducted in the Department of Agriculture at Washington as to the effect of various yeasts upon the fermentation of cider. To the various yeasts employed in fermentation are attributed the characteristic qualities of various European wines, Sherry, Burgundy, etc., and cider makers abroad are using these different yeasts in the manufacture of wines from various apple products.

Secretary Wilson in his last report for 1899 makes the following statement: "Our people have been selling apple parings, apple corings, dried apples, and cheap apples by the ton to foreigners, who, with the aid of these yeasts, have been making very desirable articles of commerce. It is designed that our own people shall have the benefit of these discoveries in the future."

Chemical Composition of a Fermented Cider.

The chemical composition of completely fermented ciders is shown from the following analyses made by the writer and Mr. C. P. Beistle, of the Pennsylvania Experiment Station, upon five samples, five to six months after pressing.

Table XI.

(Showing chemical composition of fermented ciders.)

Number.	Variety of apples.	Specific gravity.	Solids.	Invert sugar.	Malic acid.	Acetic acid.	Alcohol.	Pectin.	Ash.	Rotation 400 mm tube Ventzke scale. De- grees to left.
1	Mixed,	0.99805	1.94	0.19	0.21	0.24	6.85	0.03	0.25	2.30
2	Mixed,	1.00122	2.71	0.19	0.24	0.42	5.13	0.03	0.32	2.49
3	Mixed,	1.00525	3.26	0.89	0.30	0.48	4.67	0.05	0.29	5.28
4	Mixed,	1.00071	1.93	0.34	0.27	0.21	4.95	0.05	0.23	2.00
5	Mixed,	1.00512	2.71	0.24	0.29	1.96	4.26	0.06	0.36	1.76

The above analyses compared with the analyses of the unfermented juice of apples in Table X reveals many decided changes. The conversion of the sugars into alcohol has caused a marked decrease in solids, specific gravity, and rotation; the slight amount of sugar remaining is still sufficient, however, to produce a marked rotation to the left. All of the ciders were found to contain acetic acid, the result of a secondary acetic fermentation. The amount, however, was not sufficient to produce any marked taste of sourness, except in case of sample No. 5.

Cider Brandy or Apple Jack.—This is a product derived by the distillation of cider and should be mentioned perhaps in this connection. Its percentage of alcohol is much higher than that of the original cider; solids and ash, however, are almost completely absent. Cider brandy is not manufactured to any great extent in Pennsylvania and no investigations were made as to its chemical nature.

III. JELLY.

Cider jelly is becoming one of the most popular of the numerous food products made from the apple, and its manufacture, if properly conducted, may soon prove to be one of the most profitable side-lines open to the fruit grower.

Method of Manufacture.

In the manufacture of cider jelly for the trade, some form of steam evaporator is necessary. The old method of reducing the cider by boiling in kettles or open pans is too laborious to be profitable, and the product is much inferior in quality to that made by rapid evaporation. Thoroughly ripe and sound apples should be used in making cider for jelly purposes; the juice should be reduced as soon as pressed and as quickly as possible, to secure the best results. One hundred pounds of cider yield usually from twenty to twenty-five pounds of jelly. In making jelly for table use sugar is generally added to the cider before evaporation.

Chemical Composition of Cider Jelly.

Pure cider jelly, being simply the concentrated juice of apples, differs but little in the chemical composition of its solids from fresh cider; the main difference consists in the relative small amount of sucrose, this body being almost entirely changed, by the action of the malic acid during boiling, into invert sugar. The following analyses, made by the writer, gives the chemical composition of a sample of pure cider jelly.

Table XII.

(Showing the chemical composition of cider jelly.)

	Water.	Solids.	Invert sugar.	Sucrose.	Total sugar.	Total sugar after inversion.	Free malic acid.	Ash.	Pectin.	Rotation, 20 gms. to 100cc, 200 mm tube, Ventzke scale. Degrees to left.
Composition of cider jelly,	39.88	60.12	49.75	2.18	51.93	52.04	3.61	1.39	1.60	21.35
Jelly calculated to original juice, .....	.....	15.03	12.44	0.55	12.99	13.01	0.90	0.35	0.40	.....

The calculation to the original juice was made upon the assumption that the latter in boiling had been reduced to one-fourth of its original volume. A quite close agreement will be found between this computed analysis and analyses of juices given in Table X—the only difference consisting in the high percentage of invert sugar and the low percentage of sucrose, a fact due to the inversion of the latter during boiling, as has been explained.

Boiled cider is another product prepared by the concentration of apple juice. It is manufactured in the same general way as cider

jelly, the only difference being that the product is not so highly concentrated.

No analyses were made of boiled cider. An examination would probably show a higher percentage of water than the jelly, but no great difference as regards the composition of the solids.

The Adulteration of Apple Jelly.

The markets are flooded with a great number of fictitious fruit jellies, marked apple, peach, quince, etc., but which are really of an entirely different origin. The most common adulterant of such jellies is commercial glucose; this substance, owing to its strong dextro-rotatory properties, is most easily detected. The addition of cane sugar to jellies is a universal practice and cannot be regarded as an adulteration. The presence of cane sugar in jelly may also give a dextro-rotation to the plane of polarized light, and in order to distinguish between glucose and cane sugar, the solution of jelly is inverted with hydrochloric acid and again examined through the polariscope; if the rotation still continues to the right the presence of glucose is indicated unmistakably.

The following analysis, by the writer, of an adulterated jelly is given as an example.

Moisture, per cent.,	28.11
Solids, per cent.,	71.89
Ash, per cent.,	0.37
Rotation (26.048 gms. to 100cc) Ventzke scale, degrees to right,	100.83
Rotation (26.048 gms. to 100cc) after inversion, degrees to right,	96.46

The above analysis compared with the analysis of pure cider jelly previously given shows the widest divergence.

IV. APPLE-BUTTER.

We cannot leave the subject of apples and cider without mentioning apple-butter or "lott wahrig" as it is sometimes called locally. This product has become almost an article of necessity to the native inhabitant and no Pennsylvania farmer considers his fall work com-

pleted, if he has not made up his annual supply of this delicacy. The popularity of apple-butter, however, is no longer limited to our rural sections, but has extended to the cities, so that its manufacture on a large scale has become in some places a business of considerable profit.

Method of Manufacture.

Apple-butter is usually made by boiling together apples and cider, until the mixture is reduced to about one-third the original volume. A small quantity of ground cinnamon or other spice is then generally added for the purpose of flavoring; boiled cider, cider jelly, and sugar are also frequently mixed with the butter according to the desires of the consumer. After running through a colander to remove coarse particles, such as seeds, etc., the butter is stored in tightly covered jars.

The Danger in the Use of Copper and Brass Kettles.

In the rural districts the boiling of cider and apple butter is generally conducted in copper or brass kettles. Great care must be exercised in the use of such utensils; they should be scoured with hot vinegar and thoroughly rinsed before using, and the butter or jelly, as soon as finished, should be removed immediately. By the action of the malic acid during boiling upon the surface of the kettle, especially if the latter is tarnished in any way, a small amount of copper malate is apt to be formed and taken up by the contents of the kettle. Copper malate, like other organic salts of copper, is a virulent poison, and its presence in food materials renders the use of the latter necessarily dangerous. The apple-butter or jelly which sometimes adheres to the bottom and sides of kettles is especially apt to be contaminated, and scrapings from brass or copper kettles should never be used. Several deaths have resulted in Pennsylvania the past fall from neglect of this precaution. Wherever possible, in making apple-butter, some form of the improved steam cookers now manufactured should be used.

The Chemical Composition of Apple-Butter.

The chemical composition of apple-butter varies according to the proportions of the ingredients used and the amount of concentration during boiling. The following analyses made by the writer may be considered perhaps as typical as any. The apple-butter analyzed was manufactured by Mr. Henry Shreffler, of State College, Pa., for his own family use. Two bushels of pared and cored apples and twenty-eight gallons of cider were boiled down to about ten gallons of butter: no sugar was added.

Table XIII.

(Showing chemical composition of apple butter.)

	Water.	Solids.	Invert sugar.	Sucrose.	Total sugar.	Total sugar after in- version.	Free malic acid.	Ash.	Protein.	Apple marc.	Pectin.	Rotation, 20 gms. to 100cc, 200 mm tube, Ventzke scale. Degrees to left.
Composition of apple butter,	52.84	47.16	37.20	1.14	38.34	38.40	2.52	0.97	0.25	1.14	2.15	19.36
Apple butter com- puted to original materials, .....	.....	15.72	12.40	.38	12.78	12.80	.84	0.32	0.08	0.38	0.72	.....

The computation to original materials was made upon the assumption that the butter had been reduced in boiling to one-third of its original volume. The calculated analysis agrees closely with that of unconcentrated apple products and shows exactly what was observed with cider jelly, in that most of the sucrose originally present has been changed during boiling into invert sugar.

V. APPLE POMACE.

Chemical Composition of Apple-Pomace.

In the pressing of juice from ground apples the theoretical yield of cider is never obtained; in practice only from 70—80 per cent. of all the juice present is removed.

The following analyses were made by the writer upon a sample of whole apples and upon the pomace left after pressing the same. The grating and pressing were done at the mill of G. E. Corl, State College, Pa.

Table XIV.

(Showing chemical composition of apples and pomace therefrom.)

	Water.	Solids.	Invert sugar	Sucrose.	Free malic acid.	Ash.	Protein.
Apples,	86.88	19.12	9.86	2.17	0.41	0.32	0.44
Pomace,	70.76	29.24	8.63	1.90	0.36	0.49	1.25

It will be seen from the above analyses that the insoluble solids of the apple become concentrated in the pomace, as would be expected. The residue left after pressing still contains a high percentage of sugar, the quantity in the above instance even exceeding that found in many varieties of whole apples. The recovery and utilization of the valuable constituents of pomace are therefore points well worth considering.

Methods of Utilization.

Pomace as Fuel.—The use of dried pomace as fuel for the boiler is practiced in many cider mills. This is not to be commended however; it is wasteful, to say the least, since a large amount of sugar which might be easily recovered is simply allowed to go up in smoke.

Pomace as Fertilizer.—Considerable has been said about the manurial value of apple pomace. The value of the nitrogen, potash, and phosphoric acid in a ton of the apple pomace above analyzed, was estimated to be only about eighty-five cents, so that as far as supplying much valuable plant food is concerned pomace is not worth handling. Apple pomace has been reported as having exerted a very favorable effect upon certain soils; its high percentage of organic matter no doubt helped largely to this effect by the formation of humus. Upon certain crops, notably grass, pomace has been said to exert a deleterious effect. Whether or not this is the result of a fermentation, with the consequence of too much acid being formed in the soil is uncertain; the addition of lime in such cases might act as a corrective agent. But after all is said the use of pomace as a fertilizer is nearly as wasteful as using it for fuel; certain constituents of it, at least, can be more profitably disposed of.

Pomace for Feeding.—The use of pomace for feeding cattle and pigs has been recommended by many with great favor. Pomace itself has but a slight feeding value as compared with meal or grain; it may serve, however, a good purpose by diluting these more concentrated feeding stuffs, if fed in connection with them, affording also more

variety and relish to the ration. Pomace should not be allowed to stand until it has become sour from fermentation before feeding to animals, but should be used as soon as possible after pressing.

Repressing Pomace.—The most profitable method for disposing of the pomace from apples consists in repressing it after the addition of water in small amounts. The pressed juice from this treatment or “second pressings,” as it is called, is either evaporated for jelly or allowed to ferment for vinegar stock. Jelly made from second pressings is usually lighter colored and firmer in texture than that made from the first pressings, but lacks in flavor. The best jelly is made by mixing the juices from both pressings and running down together in the evaporator.

The manufacture of jelly and vinegar stock from second pressings is a large item in the profits of many cider factories; a larger amount of valuable material is obtained from the apple, than where the pomace was thrown away, while the residue which remains from the second pressings may still be used in any of the ways previously specified.

Chemical Composition of Second Pressings.

The composition of a sample of second pressings, made from the pomace of Table XIV, is shown by the following table; the analysis of the first pressings from the same apple is given for purpose of comparison.

Table XV.

(Showing chemical composition of second pressings and first pressings.)

	Specific gravity.	Solids.	Invert sugar.	Sucrose.	Total sugar.	Total sugar after inversion.	Ash.	Rotation, 400 mm tube, Ventzke scale. Degrees to left.
Second pressings,	1.03764	9.14	7.13	1.33	8.46	8.53	0.20	31.94
First pressings,	1.05901	13.75	10.52	2.31	12.83	12.95	0.26	44.18

While considerably inferior to the original juice in composition, the above sample of second pressings is, nevertheless, capable of producing a cider of over four per cent. alcohol and a vinegar of equal strength as regards acetic acid.

Vinegars made directly from second pressings, however, are apt to be below standard both as regards acid and solids; to prevent this the vinegar stock may be concentrated in an evaporator to the proper gravity before starting the alcoholic fermentation.

VI. VINEGAR.

Acetic Fermentation.

Vinegar, as is well known, results from the acetic fermentation of cider and other alcoholic liquids. The change under favorable conditions, takes place immediately after the alcoholic fermentation, and progresses most readily with an abundant access of air and a temperature of from 75 degrees to 95 degrees Fahrenheit.

There are a number of organisms, which produce acetic fermentation, among the most important of these may be mentioned the *Mycoderma aceti*. The spores of these germs drop from the air, like the spores of the yeast plant, and finding in the cider a liquid especially suited for their growth, multiply rapidly on the surface of the liquid, where the supply of oxygen, necessary for their growth, is most abundant. By the rapid growth of the ferment a slimy skin is formed, which finally settles to the bottom of the cask, to be replaced at once by another formation on the surface, which also settles—being in its turn replaced by a third growth. This process continues until the supply of alcohol in the liquid is exhausted when fermentation ceases. The accumulation of deposits, consisting of the ferment cells, constitutes the ordinary “mother of vinegar.”

The chemical change, which goes on in the acetic fermentation of alcoholic liquids, is simply a process of oxidation, whereby the greater part of the alcohol is converted into acetic acid. This would be shown by the following equation:



or 100 parts alcohol + 70 parts oxygen = 130 parts acetic acid + 40 parts water.

In practice the theoretical yield of acetic acid is never realized; an unfinished experiment, at present being conducted by the writer at the Pennsylvania Experiment Station, seems to indicate that only about 80 per cent. of the theoretical amount of acetic acid is attained in actual fermentation.

Methods of Manufacture.

Cask Fermentation.—This is the most common method of making vinegar; as practised by the majority of farmers, it consists simply in putting aside in the cask cider which has spoiled from souring and al-

lowing it to ferment at will. Much of the vinegar made by this process is rendered worthless from improper treatment and lack of proper care and attention, but if rightly conducted there is no doubt that the slow method of cask fermentation produces the best vinegar, both as regards flavor and acidity.

To secure the best results, only cider should be taken which has completed the alcoholic fermentation; the attempts to change fresh apple juice directly into vinegar by the addition of mother or by mixing with old vinegar are not to be commended, as the alcoholic and acetic fermentation do not proceed well together. After the alcoholic fermentation is complete, cider, for vinegar purposes, should be transferred to a warmer room of from 75 degrees to 85 degrees Fahrenheit; at this temperature the acetic fermentation will proceed more rapidly than if the cider were kept in a cool cellar. To hasten the acetification, the cider may be inoculated either by adding mother or by mixing with old vinegar. The barrels in which the fermentation is conducted should not be filled over three-fourths full, and the bungs should be removed in order to secure a proper exposure to the air. European vinegar makers usually add the cider in successive small amounts of from two to four gallons to large "mother casks," which contain simply mother and old vinegar. When these are about half-filled, one-third of the contents are siphoned off into large vats, where the fermentation is completed. The addition of cider to the mother casks is kept up, so that the process becomes really a continuous one. The mother casks can be used in this way an indefinite period, until the accumulation of sediment necessitates their being cleaned.

Generator Vinegar.—The great length of time required to make vinegar by the cask fermentation method has led to the adoption in many places of vinegar generators, by means of which alcoholic liquids can be converted into vinegar in the course of a few hours.

The generator consists usually of an upright cask from three to five feet in diameter and from six to twelve feet high. About a foot from the bottom of the cask a perforated false bottom is fastened, and upon this beech shavings are placed until the cask is nearly full; the shavings which are used should be previously boiled in water and then, after drying, soaked for several hours in old vinegar. A perforated disk is then placed above the shavings, and the cask closed on top by a cover having a hole in the centre, through which the cider enters the generator. Just under the false bottom a row of holes is bored, slanting downwards and extending around the cask in a line parallel with the bottom.

When everything is ready the cider, which is to be converted, is allowed to run through the hole in the cover upon the perforated disk, through which it is evenly distributed upon the surface of the shavings. The rate of flow depends somewhat upon the size of the gen-

erator, but as a rule it should not exceed a gallon an hour. During the oxidation of the alcohol considerable heat is produced, which causes a current of air to enter through the air holes at the bottom and pass upward through the shavings. The temperature of the generator should be observed from time to time by means of a thermometer inserted into the shavings through a hole about half way up the cask. It has been found that a temperature of 95 degrees Fahrenheit secures the best results; a heat much above this point will cause a loss of alcohol from evaporation, whereas below this degree the acetification proceeds too slowly. To reduce the temperature the supply of air is cut off by plugging the holes at the bottom, while to raise the temperature the air supply is increased. The process, being one of oxidation, is perfectly analogous to that of operating a stove or furnace, where the heat is regulated by opening or closing dampers.

A barrel of cider, which might require two or three years for complete conversion into vinegar by the method of cask fermentation, can be changed in as many days by the generator process. The product by the latter method is also apt to be more uniform in composition than that obtained by the former process, since the conditions affecting the acetification can be more easily controlled. It is admitted, however, that generator vinegar, in aroma and flavor, is not equal to vinegar made by the longer process—the delicate and volatile esters, which give the latter vinegar its peculiar properties, being the products of a slower and less violent fermentation. For a table vinegar the old process of fermentation is to be preferred, while for pickling and similar uses, generator vinegar is no doubt as well suited as a product of the former kind.

Chemical Composition of Vinegar.

The chemical composition of cider vinegar is shown from the following analyses which were made by the writer upon four samples of known purity.

Table XVI.

(Showing chemical composition of four pure cider vinegars.)

Number.	Maker.	Kind of apples.	Specific gravity.	Solids.	Acetic acid.	Pectin.	Ash.	Invert sugar.	Rotation, 400 mm tube, Ventzke scale. Degrees to left.
1	W. C. Patterson, State College, Pa.,	Mixed,	1.01550	1.44	6.23	0.09	0.30	0.47	2.01
2	W. P. Fisher, Unionville, Pa.,	Mixed, ...	1.01425	1.75	4.33	0.13	0.43	0.20	0.96
3	W. P. Fisher, Unionville, Pa.,	Mixed, ...	1.01625	2.10	4.26	0.19	0.43	0.67	2.27
4	W. P. Fisher, Unionville, Pa.,	Sweet Vandevere,...	1.02750	2.72	9.96	0.25	0.57	0.75	2.94

No alcohol was found in any of the above samples. A small amount of invert sugar was found in every instance—this substance being present in sufficient quantity to give a distinct laevo-rotation to all vinegars. Particularly noticeable is the high percentage of acetic acid in No. 4; other samples of Sweet Vandevere vinegar obtained from Mr. Fisher exhibited this same peculiarity. Samples of Sweet Vandevere apples and of new cider therefrom, obtained from Mr. Fisher, showed upon analysis only an average amount of sugar, so that the writer is unable to explain this high percentage of acetic acid only upon the basis that ciders from sweet apples give much nearer the theoretical yield of acetic acid than ciders from sour or mixed varieties. It is possible that malic acid is unfavorable towards complete fermentation and the popular saying, “sour apples for cider and sweet apples for vinegar” may have, therefore, some scientific foundation.

Uncomplete Fermentation and its Effects.

Owing to the great length of time required in making vinegar by the slow process of cask fermentation, farmers are often too hasty in putting their products upon the market, with the result that the acidity is frequently below standard—a considerable amount of alcohol still remaining unconverted. The following cases, taken from a large number of vinegars analyzed by the writer, illustrate this.

Table XVII.

(Showing four instances of uncompletely fermented vinegars.)

Number.	Specific gravity.	Solids.	Acidity.	Alcohol.	Ash.
1.	1.0076	3.02	1.52	4.04	0.23
2.	1.0063	1.61	3.23	2.05	0.28
3.	1.0050	1.36	2.60	2.21	0.28
4 (second pressings stock),	1.0063	2.72	1.15	4.61	0.50

The Adulteration of Cider Vinegar.

No product of the apple is subject to more adulteration than vinegar; a circumstance due to the fact that no product of the apple is in more universal demand. Owing to the higher price which cider vinegar brings over other kinds, there exists a great temptation for the unscrupulous dealer to "doctor" the cheaper grades by the addition of various substances and sell the counterfeit as a pure cider vinegar.

The addition of water to vinegar was formerly a common method of adulteration, but since the enforcement of the vinegar law the practice has become less frequent. Such an addition will necessarily decrease the solids and acidity. According to the Pennsylvania law no vinegar should go below four per cent. acid and 1.5 per cent. solids. There is no doubt but that all ciders, if properly fermented, will give the above percentage of acid; as regards solids, however, the law is too severe. Many cider-vinegars of known purity have been found by the writer to give less than 1.5 per cent. of solids (e. g. vinegar 1, Table XVI).

The most common method of adulterating vinegars, practiced at the present time, consists in taking the cheaper "distilled" and so-called "white wine" vinegars and supplying the solids which these brands lack by the addition of caramel, molasses, sugar, glucose, or cider jelly.

An unalterable characteristic of cider vinegar, as of all other apple products, is the laevo-rotation of the plane of polarized light. The addition of cane sugar or molasses to a vinegar will cause a deflection of the plane of polarized light to the right, by inversion with acid the rotation will be changed to the left. The presence of these bodies will also be indicated by a marked increase in the copper reducing power after inversion. Inversion with acids will produce no change either in rotation or copper reducing power of a pure cider vinegar.

The following analysis was made by the writer upon a sample of vinegar sold in Lock Haven, Pa., as a pure cider vinegar, but which an examination showed to be adulterated with sugar or molasses. The analysis of a genuine sample of Sweet Vandevere vinegar is appended for comparison.

Table XVIII.

(Showing adulteration of vinegar by sugar or molasses.)

Sample.	Specific gravity.	Solids.	Ash.	Acetic acid.	Pectin.	Rotation, 400 mm tube, Ventzke scale.	Reducing Sugar.		Sucrose.
							Before inversion.	After inversion.	
Lock Haven, adulterated,	1.02335	3.59	0.36	4.26	0.57	+1.88†	1.43	2.05	0.59
Sweet Vandevere, genuine,	1.02750	2.72	0.57	9.96	0.25	-2.94†	0.75	0.70	.....

In case the dextro-rotation of a vinegar should persist even after inversion, the presence of glucose is assured.

One of the most subtle methods of sophistication practiced at the present time consists in correcting the deficiency in solids of a vinegar by means of cider jelly. We have here all the elements which make up the solids of a pure cider vinegar. An examination of the ash, which in many cases is of great value, would in this instance be of no use since the ash of cider jelly and of cider vinegar is alike in composition.

In such cases the high percentage of reducing sugar, together with an excessive laevo-rotation is usually indicative.* The following analysis made by the writer upon a vinegar from Butler county is illustrative of this.

Table XIX.

(Showing a vinegar adulterated with cider jelly.)

	Specific gravity.	Solids.	Acetic acid.	Ash.	Reducing Sugar.	Rotation 400 mm tube, Ventzke scale. Degrees to left.
1,	1.0287	4.12	6.41	0.45	2.53	15.8

*For a very full discussion of this method of adulteration see article by Dr. Wm. Frear, 1897, Rep. Dept. of Agr. Pa., p. 138.

†+ = rotation to right, - = rotation to left.

The above analysis shows a startling difference in solids, sugar, and rotation, when compared with the genuine samples of Table XVI.

A large number of fictitious vinegars are at present being manufactured by means of ordinary acetic acid or of the so-called vinegar essences. We quote the following from a letter of a manufacturer of such products:

"The price of our pure acetic acid 80 per cent. in single barrels is \$6.40 per 100 pounds; vinegar essence 80 per cent. \$7.40. Both these goods are used exactly alike; that is, take one gallon of either and mix same with eighteen gallons of water, and you will have nineteen gallons of the standard strength of vinegar, viz: forty-five grains or four and one-half per cent."

"If you wish to make vinegar alone with our goods, we would advise you to use our vinegar essence. If, however, you should wish to mix this acetic acid vinegar with other vinegar, as cider or white wine vinegar, we would advise you to use nothing but our pure acetic acid. If the vinegar is short in solids, add the required solids, using burnt sugar, starch, glucose, or some such substance."

Samples of the acetic acid and vinegar essence referred to above were analyzed by the writer with the following results:

Table XX.

(Showing composition of materials used for adulterating vinegar.)

Product.	Specific gravity.	Acetic acid, per cent.	Solids.
Acetic acid,	1.06921	76.9	.....
Vinegar essence,	1.06444	64.8	0.03

The analysis show that these adulterants were in one sense themselves adulterated products, by being below guarantee in acetic acid. The essence had a little coloring matter added, and was strongly flavored with acetic ether.

Before concluding, the writer desires to acknowledge courtesies extended by Dr. H. P. Armsby, Dr. Wm. Frear, Prof. G. C. Watson, Prof. G. C. Butz, and Mr. J. P. Pillsbury, of the Pennsylvania State College Agricultural Experiment Station, also by Mr. W. P. Fisher, of Unionville, Pa.

Mention should be made also of the following works consulted by the writer in the preparation of this bulletin:

Eleventh Census of the United States, 1890.

Structural Botany, by Gray.

Physiological Botany: Goodale.

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Nahrungsmittel: König.

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The Utilization of Unmerchantable Apples: Alwood, Bulletin 57, Virginia Experiment Station.

An Experiment in Generating Vinegar: Alwood, Bulletin 57, Virginia Experiment Station.

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Apples in Pennsylvania: Butz, Pennsylvania State College Experiment Station, Bulletin No. 43.

Fermented Alcoholic Beverages: Crampton, Bulletin No. 13, Division of Chemistry, United States Department of Agriculture.

Zinc in Evaporated Apples: Wiley, Bulletin No. 48, Division of Chemistry, United States Department of Agriculture.

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